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BWW Ontology as a Lens on IS Design Theory: Extending the Design Science Research Roadmap

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Abstract.. The Design Science Research Roadmap (DSR-Roadmap) [1] aims to give detailed methodological guidance to novice researchers in Information Systems (IS) DSR. Focus group evaluation, one phase of the overall study, of the evolving DSR-Roadmap revealed that a key difficulty faced by both novice and expert researchers in DSR, is abstracting design theory from design. This paper explores the extension of the DSR-Roadmap by employing IS deep structure ontology (BWW [2-4]) as a lens on IS design to firstly yield generalisable design theory, specifically 'IS Design Theory' (ISDT) elements [5]. Consideration is next given to the value of BWW in the application of the design theory by practitioners. Results of mapping BWW constructs to ISDT elements suggest that the BWW is promising as a common language between design researchers and practitioners, facilitating both design theory and design implementation.

Keywords: Key Words: Design Theory, IS Ontology, Design Science Research Methodology, DSR-Roadmap, Design Ontology

1 Introduction

Design Science Research (DSR) has become an accepted approach for research in the Information Systems (IS) discipline [6, 7], with dramatic recent growth in related literature [8]. However, there is a lack of consensus on DSR methodology [9, 10] and DSR outputs [11, 12], indicating that DSR in IS is still in its genesis [13, 14]. Views and prescriptions on the methodology of DSR appear disparate, e.g. [9, 15-21]. Evidences and observations have shown a lack of accepted, detailed guidance, and consequent methodological shortcomings in much DSR [10, 22-24]. Hence, there appears to be a need for a structured, detailed, comprehensive, integrated and validated DSR methodology in the IS discipline.

Prior work in this direction by Alturki et al. [1] resulted in the IS DSR-Roadmap (DSR-Roadmap), a structured and detailed methodology for conducting DSR, spanning the entire DSR lifecycle from the early 'spark' of a design idea through to final publication (see Figure 1).[1] It usefully inter-relates and harmonizes various otherwise seemingly disparate, overlapping or conflicting advice and concepts reported in the

[1] It is compressed because of space limitations. For the readable version, please see Figure 1 in [1, 25].

literature. The DSR-Roadmap consists of the following four main interrelated components (explained in detail [1]): (A) Activities and Cycles; (B) Output, which adopts Gregor and Jones' IS Design Theory [5]; (C) Risk Management; and (D) the Central Design Repository (CDR). Component (A) incrementally populates as well as draws from component (D), which ultimately contributes to component (B). Component (C) and Component (A) are executed in parallel, both again using component (D). Consequently, Components (B) and (D) are the sources that contribute to both practice and knowledge base. The DSR-Roadmap continues to be validated and to evolve based on evaluation findings[2].

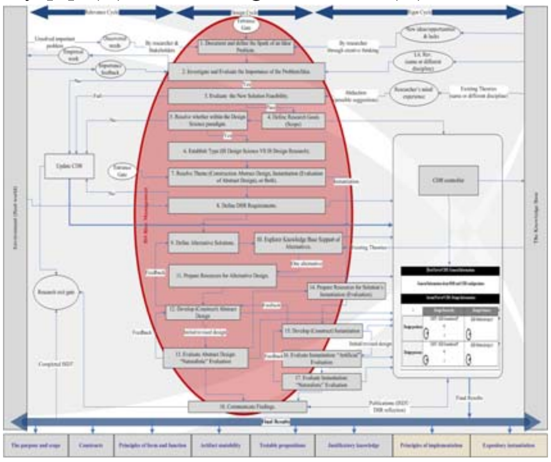

Fig. 1. – The DSR-Roadmap

In achieving the principle objective, namely the DSR-Roadmap, the current study requires that the DSR-Roadmap presents all components in the DSR methodology. Although the DSR-Roadmap was evaluated and refined in different ways [39], it is still evolving. One aspect that it should have is the attributes or constructs that researchers must be aware of in DSR in order to describe their design; what things they need to describe and attain for the best design theory and instantiation.

Types of DSR outputs include: constructs, methods, models, instantiation, and design theory [5, 27-30]. Close attention to design definitions in DSR literature reveals that design in DSR can be viewed as a process or a product [27, 30]. These aspects on the design may justify the diversity in DSR outputs. DSR literature also reveals that few scholars focus on the design in terms of which general and detailed constructs should be considered, except for design requirements and functions. Walls et al. [30], Gregor and Jones [5], and Baskerville et al. [29] believe the design theory is the ultimate output of DSR in IS. They contribute to the design definition by proposing different structures of design theory. Others (e.g. Lee et al. [31] and Venable [32]) contribute to theorizing framework in DSR. Although these seminal efforts have proposed abstract representation of the abstracted design in the form of design theory, there is a need for general yet detailed constructs to describe the design.

More specifically to the DSR-Roadmap, the ISDT proposed by Gregor and Jones [5] is adopted as the primary output component in the DSR-Roadmap, because we believe it is the most comprehensive DSR output [1]. Nonetheless, we believe that in their abstract form, elements of the ISDT are not easy for design researchers to populate. Neither do the abstract elements readily facilitate practitioner construction of the intended system. Instead, researchers are required to transform instantiated knowledge

[2] See formative evaluations of the DSR-Roadmap reported in [25, 26]

into many forms until the abstract knowledge is developed and populated in the ISDT's elements, and then practitioners transform the abstract knowledge in the ISDT into many forms until the instantiation in specific context is developed, ready to implement and program (or to be read by a machine[3] [2-4]). The question here is: Can design researchers populate the elements of ISDT and then implement ISDT easily in the absence of detailed constructs? Thus, it is desirable for design researchers to have a list of design constructs which they can easily utilize to develop a comprehensive and implementable design theory; theorizing/abstracting and instantiation/de-abstraction respectively.

Published in their seminal work on IS Deep Structure[4] [2-4], and based on Bunge's [34, 35] basic ontology, Wand and Weber's 'BWW ontology' has been used extensively in IS research for a range of purposes [36]. Alturki et al. [37] describe the relationship between DSR and the core of IS [2-4]. Herein, BWW is considered for inclusion in the DSR-Roadmap [1] as a bridge (transition tool) between the DSR Activities and Cycles component, the ISDT component (abstracted), and artifact (instantiated). It is posited that the BWW ontology may provide design researchers with most, if not all, design constructs that are needed to describe their design.

Therefore, this paper seeks to propose design constructs for DSR in IS. This objective motivates the investigation of the applicability of the BWW ontology constructs for DSR in IS, specifically the inclusion of the BWW ontology in the DSR-Roadmap (DSR Methodology). This paper suggests the BWW ontology as a tool that allows researchers in DSR to produce design theory and convey their design to both academics and practitioners; hence, a tool to communicate design specifications of DSR in IS. This investigation is conducted by mapping between the BWW ontology constructs and Gregor and Jones' [5] ISDT elements.

The effort in this paper contributes to DSR by providing researchers in DSR with detailed design constructs (linked to ISDT elements) to promote a comprehensive yet parsimonious design, while also easing communication and implementation of their design. Researchers in DSR will benefit from these design constructs to guide them in design theory development. Articulating and specifying these design constructs constitutes sufficient base for design theory development. We believe these constructs to be a vehicle for developing a strong complete design and improving its quality, because design researchers will be aware of various detailed aspects of an imagined design solution. Similarly, Wand and Weber believe any representation tool, a design in essence, is not complete if the BWW ontological constructs are not considered [4]. Thus, the BWW ontology will explicitly strengthen the design of artefacts.

The remainder of the paper is organized as follows. First, we review the literature to provide an overview of the design nature in DSR and briefly explain the BWW

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[3] From here onwards we use 'read by machine' so as to be consistent with Wand and Weber's terminology.

[4] Benbasat considers this work as one of the few ground-breaking efforts that challenge our thinking and lead to new exciting directions in research and teaching. We assume the reader is familiar with internal and external IS views proposed in [4, 33]. IS Deep structure, part of the internal view, describes the characteristics of the real-world phenomena that the IS is intended to represent, such as Entity Relationship Diagrams.

ontology constructs. Then we justify why the BWW ontology is suitable for use in Design Research. In Section four, we illustrate and discuss the integration of the BWW ontology into the DSR-Roadmap through a mapping exercise between the BWW ontology constructs and ISDT's elements, showing the results of this mapping. We conclude by summarizing the paper's contributions and future work.

2 Literature Review

2.1 The Nature of "Design" in Information Systems Design Science Research

This section briefly presents an overview on the nature of the design definitions in DSR showing that these definitions range between design as process and design as product. In general, to design may be a verb referring to the performance of a design, a noun referring to the constructed artefact, or it can refer to the utility set in the artefact[5] [38]. Design is a constructive action that results in a product. Walls et al. [30] see design as both a noun and a verb, because it is a target object that will be constructed and an action (design) that fulfils design requirements. It describes the world as acted upon (processes) and the world as sensed (artefacts) [27]. Alexander (1969) cited in [30] distinguishes between scientists and designers. While the role of scientists is to discover the components of a system of interest, the role of designers is to shape those components. Synthesis is the essence of the design.

'Design' is "from the Latin désigńare, which means to point the way" [38]. Simon [39] sees design as creating options that are filtered and excluded until the design's requirements are fulfilled. Hevner et al. [27] believe design is a search activity that aims to find the best solution for important unsolved problems. Design includes creating new things, solving problems and moving to desired situations from less preferred situations [40]. The design is "[t]he use of scientific principles, technical information and imagination in the definition of a structure, machine or system to perform pre-specified functions with the maximum economy and efficiency" (Fielden cited in [30]). It involves building a solution intended to resolve a problem [9].

The design describes an artefact's organisation and functions [39]; yet few researchers describe this organization. In his seminal work Simon [39] describes an artefact as a meeting point – an interface – between the inner and outer environments. The inner environment is "the substance and organization of the artefact itself" [39]. The outer environment is "the surrounding in which the [artefact] operates". The artefact will achieve its anticipated objectives if the inner environment is suitable for the outer environment. The artefact's goals link the inner to the outer environment. The artifact's behaviour is forced by both its inner and outer environments; the artefact is 'structurally coupled' to its environment. The outer and inner environments are connected through the afferent (input) channel and efferent (output) channel. The former "receives information about the environment"; the latter "acts on the environment" [39]. The 'bringing-to-be' of an artefact's components and organization, which interfaces in a desired manner with its outer environment, is the design activity [20]. De-

[5] In this paper we are interested in the first two meanings.

sign is "shaping artefacts and events to create a more desirable future" (Boland cited in [17]).

Although most DSR methodological contributions mention 'design' as a key step in conducting DSR, e.g. [9, 17, 18, 20, 21], these methodologies have not focused on the design in terms of what attributes and constructs should be considered[6].

Scholars' definitions of design mentioned above are general and fluctuate between design as process and as product. They consider design as a creative process [27, 39] and for this reason, they may leave details to the creativity of design researchers. While we accept and value these high level definitions, we believe there is merit in exploring potential constructs and specification for design in general and specifically as product before (theorizing) and after (instantiation) it is theorized. It is advantageous to propose design constructs for IS DSR which allow design researchers to describe their design using limited constructs during the design process.

2.2 An Overview of IS Deep Structure Ontology Constructs

This section explains the BWW ontology constructs proposed by Wand and Weber [2-4, 33, 41] based on the seminal work of Bunge [34, 35]. Ontology is concerned of the structure of the real world; it is a school of thought that studies the existence of things. The BWW ontology defines the "set of constructs that are necessary and sufficient to describe the structure and behaviour of the real world" [33]. Since ontology concerns the structure of the real world, it is relevant to perceive IS from two points of view: 1) IS represents the real world; therefore, ontology provides the basic things in the real world that IS ought to be able to symbolize; 2) IS itself is an object in the real world because IS is also things in the real world; hence, ontology provides a basis for modelling [41]. Both views are important to our argument, but we are mainly concerned with the first view, because it directly enriches our discussion. This set of core ontological concepts can be used to illustrate the structure and behaviour of a designed IS which is representational of the real world [4].

Wand and Weber propose three models for IS deep structure: 1) representation model, 2) state track model, and 3) decomposition model. We believe the three models are relevant to the design product, but this paper focuses on the representation model. The representation model defines a set of constructs such as thing, state, properties, and transformation (see appendix A and Table 1 in [3]) which Wand and Weber believe is necessary and sufficient to describe the structure and behaviour of the real world in which IS operates. Wand and Weber believe these constructs have the ability to serve as the basis for any IS development (Routine Design explained later in the paper) uses representation language.

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[6] We are aware of influential papers that describe the structure of the abstract design in the form of design theory [5, 29, 30].

3 The Rationale of Integrating the BWW Ontology with Design Research

Based on the preceding definitions and views of design, we argue that the ultimate objective of design in IS DSR is to design and develop an artefact (IS) in response to un/conceivable unsolved problems or to satisfy un/conceivable needs. This objective may include intermediate forms of artefact, such as method, before constructing a complete automated IS. In this section, we present our argument for the applicability and inclusion of BWW ontology by Wand and Weber [2-4, 33] to DSR in IS. The argument is based on: (1) IS consisting of Routine Design and Design Research; and (2) the integration between the DSR-Roadmap components, Activities and ISDT components.

For the first point, based on the distinction between Design Research and Design Science[7], Alturki et al. [37] argue that Design Research, as a type of DSR, is a part of the IS discipline. They propose that IS deep structure in Wand and Weber's view is divided into two parts: 1) Routine Design, and 2) Design Research[8]; see Figure 3 in Alturki et al. [37] for the relationship between the IS discipline (deep structure) and DSR in IS (Design Science and Design Research) and Routine Design.

Thus, based on the relationship between DSR and IS mentioned above, and using logical deductive reasoning, we argue that anything is applicable for IS deep structure as well as for Design Research and Routine Design. Consequently, we propose the ontology of IS deep structure developed by Wand and Weber [2, 3] and Weber [4] is applicable to Design Research as well.

For the second point, the DSR-Roadmap presented in [1, 25] proposes an integration between Activities and ISDT components. While the Activities component develops the design knowledge, the ISDT component codifies design knowledge in scientific structure and organization. In other words, the content of the ISDT component results from the Activities component. Piirainen and Briggs [42] believe that the DSR methodology mirrors the structure of the design theory. They "claim that the DSR methodology and DT [Design Theory] complement the DSR framework and give additional guidance" (p. 50). Furthermore, since the ISDT is a general representation of design knowledge and an intersection point practitioners, there is a need to make its construction and implementation much easier. Thus, there is a need to ease the transition (theorizing) from designed artefact to

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[7] There are two types of DSR: 1) "design research is aimed at creating solutions to specific classes of relevant problems by using a rigorous construction and evaluation process, [2)] design science reflects the design research process and aims at creating standards for its rigour" [10]. Kuechler and Vaishnavi [7] have a similar view, and see DSR in the IS field as research with design as either a topic or method of investigation; for more details see [37].

[8] Routine Design usually solves problems using current knowledge, state of practice, techniques and available components to produce a product without the creation of any additional knowledge. DSR, on other hand, produces new knowledge that yields value from a number of unknowns in the proposed design which were successfully overcome [20].

design theory and vice versa in (instantiation); which will enable direct and clearer interactions between them.

Consistent with the two design's views, of design as product and as process, Table 2 in [5] depicts the elements of ISDT. Focusing firstly on the design product, it is clear that core elements such as construct and principle of form and function are about the design as product. These elements are about the structure, properties, functions and requirements etcetera of an artefact. For the design process, the DSR-Roadmap has been developed to help design researchers conduct DSR. The Activities component includes determination of the artefact's functionality, architecture and properties, then building an instantiation which is the physical artefact [5, 8, 9, 27, 28, 30, 38, 43, 44]. The integration between the DSR-Roadmap's Activities and ISDT components provides consistency between the design as process and design as product results from DSR.

Since the two views of the design are two sides of the coin, the mapping between them is very advantageous. This association will work as a bridge between the Activity and ISDT components. On one hand, since ISDT, a formal representation (language) of the abstract design knowledge, is the output of IS DSR, this linkage using the BWW ontology works as a tool to achieve generalizability in ISDT theorizing. Thus, this mapping helps to easily populate and enrich the elements of ISDT. On the other hand, association helps to instantiate ISDT for a particular context for a specific problem. By using the BWW ontology constructs such as thing, state, and transformation [2-4, 41], researchers will have most of the needed constructs to produce a complete design theory and an artefact.

Although we justify integrating the BWW ontology into the DSR-Roadmap, it is difficult to assert the suitability of this inclusion without showing evidence to support this claim. The subsequent section explains how the BWW ontology is integrated into DSR in IS and linked with ISDT component presenting extended layers of ISDT.

4 The Integration between Information System Ontology and Design Science Research

This section is divided into three main subsections. In Subsection 4.1, we illustrate the role of the BWW ontology to DSR in IS. Next we explain the approach followed in the mapping between the BWW ontology and the ISDT elements to include the BWW ontology in DSR in IS, specifically in the DSR-Roadmap. The result of the mapping[9] exercise and its discussion are shown in Subsection 4.3.

4.1 The Role of Information System Ontology in Design Science Research

The role of the BWW ontology in IS DSR is explained diagrammatically in Figures 2 and Figure 3. The two figures relate to each other. Figure 3 is more detailed and can be considered as a lower level representation of Figure 2 which is relatively abstract.

[9] It must however be noted that the mapping activity is tentative.

The notions in these two figures10 are developed based on the theoretical foundations in IS DSR works [5, 31, 38] and the BWW ontology in [2-4, 33].

Figures 3 and 4 are grounded on Purao's ontological view of DSR that an "artifact progresses from an idea to a 'thing in the world' … [in]… several moves back and forth" [38]. Figures 3 and 4 are also based on Gregor and Jones [5] who believe that a "design theory instantiated would have a physical existence in the real world". These figures are consistent, and represent 'Design Theorizing Framework' [31] with details by employing the BWW ontology. Furthermore, Weber states "theories provide a representation of someone's perception of how a subset of real-world phenomena should be described. In this light, they can be conceived as specialized ontologies – instances of general ontology" [45]. Design Theory is no exception.

Firstly, Figure 2 depicts the use of the BWW ontology by researchers in design research (part of DSR) to represent and perceive the real world, their minds, or both for conceivable/unconceivable[11] problem/need, and then solution/innovation – see the box titled 'Part of DSR using BWW Ontology'[12]. Since DSR in IS is intended to be a representation of un/conceivable problem/needs and a solution [1] in the designers' minds and imagination, design researchers should have a group of constructs which are able to represent and symbolize these things, which leads to the design theory.

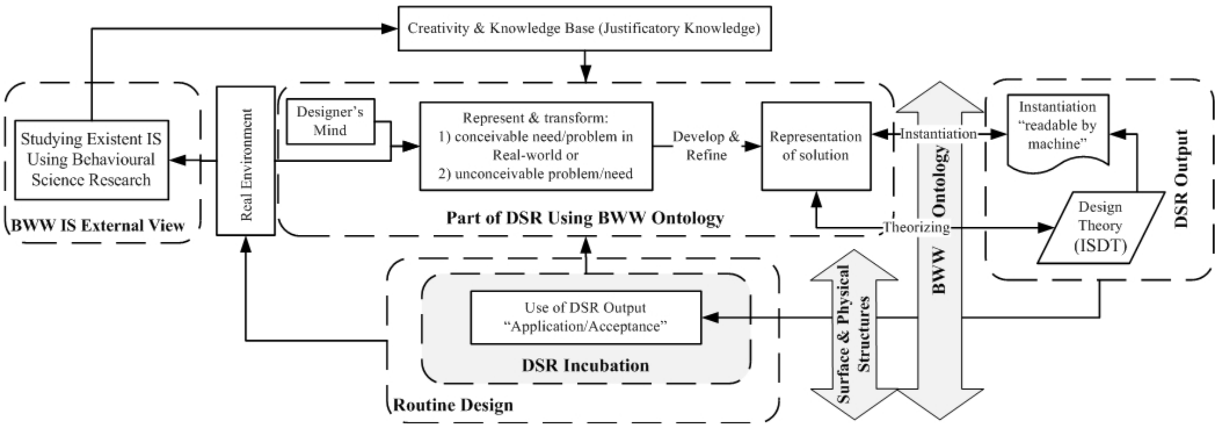

Fig. 2. The Role of BWW Ontology in IS DSR Lifecycle

The BWW ontology eases the construction of the ISDT by generalizing the content of the BWW ontological constructs. BWW ontological constructs can be used in the following DSR scenarios: 1) design researchers firstly develop abstract design knowledge (which includes an abstract problem and solution) and populate the elements of the ISDT. Then this abstract knowledge is tested and proved by developing

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[10] As the DSR-Roadmap is the principle aim of the study, Figures 3 and 4 will be considered and integrated in the DSR-Roadmap to complement its components.

[11] Conceivable means a design may target a problem/need that people experience; unconceivable means a design may target a problem/need that is not on the horizon. Unforeseeable/seeable might be equivalent to unconceivable/conceivable, respectively.

[12] Note: this box is part of DSR and other activities such as evaluation that are not represented in Figure 2 and 4.

an instantiation, for instance solution and problem. 2) Design researchers firstly develop an artefact for instance solution and problem, and then they extract the abstract design knowledge, abstract problem and solution, to populate the elements of ISDT. 3) Design researchers develop the abstract design knowledge, abstract problem and solution, to populate the elements of ISDT, leaving the instantiation construction for others, or they just develop an artefact for instance solution and problem. In any scenarios, there are a number of iterations; emerging knowledge from instantiation construction can complete and amend the design theory (ISDT elements) and vice versa; see the arrows between the BWW ontology and output boxes.

Subsequently, successful instantiation and newly emerged design knowledge in ISDT become available to be implemented by practitioners and other design researchers in DSR incubation, and then in Routine Design. The knowledge in ISDT will be used through the BWW ontology in combination with surface and physical structures[13] [3, 4]. The BWW ontology facilitates specifying all aspects of ISDT to be used by designers in their contexts. Any required refinements emerged from DSR incubation, and Routine may spark DSR. Finally, a new artefact and possible phenomenon become part of the real world, which could be a subject for IS researchers to study from the IS external view through behavioural science research. Knowledge emerging from IS external view may again spark a new design idea, which initiates a new IS DSR cycle.

Figure 3 provides details to better explain the integration of the BWW ontology with IS DSR. The three axes in Figure 3 relate to: 1) Innovation (Y axis); 2) Reality (Y axis); and 3) Representation (X axis). The Y axis symbolizes both innovation and reality, with innovation ranging from low to high, and reality ranging from real systems to abstract systems. Representation is reflected on the X axis, with the degree of representation in IS construction increasing from left (low) to right (high). Figure 3 also combines the two main IS deep structural parts, as shown in Figure 2: Design Research and Routine Design. Any point of the Design Research and Routine Design can be described in terms of the three axes. For example, ISDT is more abstract than instantiation in terms of reality; both are high in terms of representation.

In order to grasp Figure 3, we start with Routine Design (blue area) as it represents the ordinary IS development. Routine Design starts with analysing a real system to convert it into different types of transformations using different language grammar tools such as ERD, flowchart etcetera until the last transformation is automated (code) which is readable by computers/machines [2-4]. The objective here is the automation by representing the real system in IS. Here there is no need to search the knowledge base to find a solution, or generate new knowledge from the solution. The used grammars in this transformation should have good consistency with IS ontological constructs, otherwise deficiencies may appear in IS as a result of inconsistency, e.g. two or more real objects are represented by one thing in IS [4]. The Routine Design takes the existing real system and converts it to another system called IS to represent the real situation to attain several benefits, such as quick reporting and simple obser-

[13] We assume the reader is familiar with the surface and physical structures as part of Wand and Weber internal IS views proposed in [4, 33].

vation. The reader should note that Routine Design only starts from the real world, as shown in Figure 3.

In contrast, Design Research (yellow area) could spark from two possible worlds: part of the real world and the virtual world.[14] For the former (see box titled 'Real World'), Design Research starts from the existent important unsolved but foreseen problem/need. The second sparks comes from the virtual world (see box titled 'Virtual World'); there is no existent problem/need in the current setting, but through the creativity of design researchers, an interested problem/need could be envisaged. In any case, design researchers should represent the problem/need for two main reasons: 1) to help them discover a design solution, and 2) to understand and emphasize the importance of a problem/need since it is unlikely a complete and good design will result if the design researchers' efforts are wasted in the wrong parts of the problem space [46]. Without representing all aspects of the interested problem/need in the IS DSR scope, design researchers may be unable to produce a comprehensive[15] designed solution. Yet it could happen serendipitously if they are really expert and lucky; they may represent unconsciously. The best problem/need representation the design researchers develop, the best design they may construct. For the second spark, the representation may be more important and essential than the representation in the former spark.

Subsequently, both sparks, part of the real world and the virtual world, have a similar problem solving process. Design researchers search for a solution for the interested problem/need, for which then they have two paths/options towards completion of DSR, namely the '*Red path and the Blue path'*. Designers can execute these two paths separately, complete one and then start the other, or alternately, execute them together in any combination. Consistent with the design theorizing framework [31], these two paths represent the *'Abstract Domain'* (arrows in the Red path) and *'Instance Domain'* (arrows in the Blue path) proposed in [31]. Most of the arrows in Figure 3 are bidirectional, which means designers can move forward and backwards inside one domain, or in between the domains representing the DSR's highly iterative characteristic. Furthermore, black arrows correspond to shifts alternating between these two domains, representing the instantiation process or the so-called de-abstraction [31] and theorizing process or the so-called abstraction [31], respectively[16].

Once the design in the Design Research area is instantiated successfully, ISDT (including abstract problem/need and design) become an existent part of the real world; it physicalizes what was in the designers' mind. In other words, the output of the Design Research becomes an input of Routine Design as depicted by the curved line between the yellow and blue areas in Figure 3. The different intermediate outputs

[14] The real world and the virtual world contain a range of problems and needs that can be imagined or are beyond the imagination.

[15] We acknowledge Ciborra's [47] 'tinkering' concept as a very important, and perhaps the only, path to really innovative system designs. We agree with this concept yet though it is not totally congruent with our thinking, it is a valuable and effective in enhancement process when shortcomings discovered in design.

[16] In other efforts we find it empirically important to represent theorizing and instantiation in the DSR-Roadmap.

such as models and methods could be developed during the Design Research progression.

Although different types of transformation in DSR are applied, there are no common or acceptable constructs used that allow design researchers in IS DSR to specify their design entirely in order to help them to theorize design theory, ISDT structure, and then implement the design. In the next subsection, we address the following issue: Can design researchers populate the elements of ISDT and then implement ISDT easily?

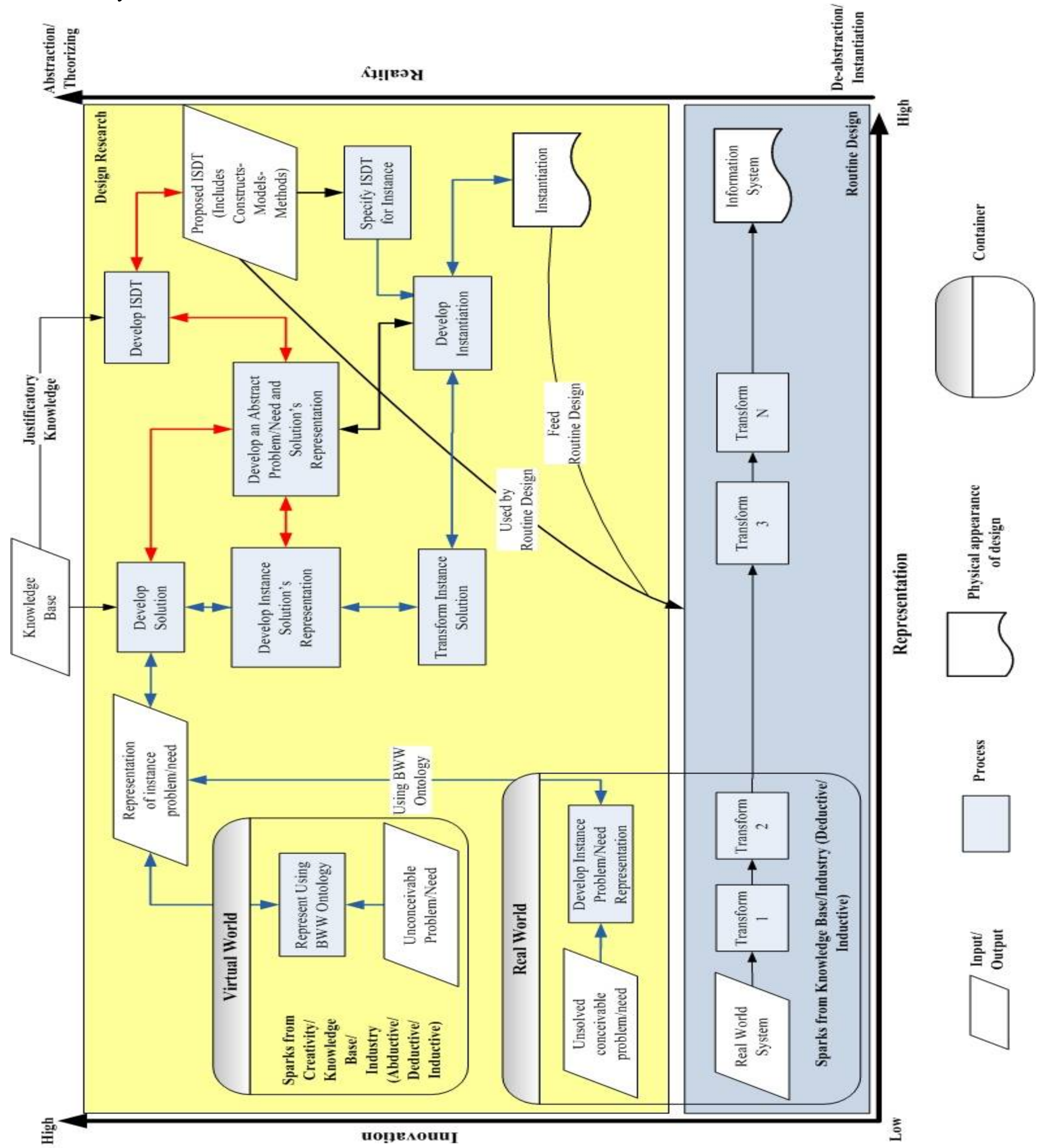

Fig. 3. Details of IS Ontology Role in IS DSR Lifecycle

4.2 The Approach of the BWW Ontology and Information System Design Theory Elements Mapping Exercise

In order to achieve rigorous results, we follow a similar approach to the procedural approach in [48]. This approach consists of three main steps; however, we split the first step into two steps, and due to single author coding, the last step in the procedure is marked for future work, as described below:

(1A) the process starts by distilling key aspects in each element of ISDT by breaking down each element of ISDT into micro building blocks. The objective here is to help the researcher in the mapping exercise to check the consistency between ISDT elements and the BWW ontology constructs and then he can conclude the applicability of the BWW ontology constructs to DSR. (1B) The researcher goes through the BWW ontology constructs one by one, listed in Appendix A, and has complete close readings to get sufficient understanding. 1a and 1b are relatively similar to work in [49]. (2) The researcher links the ISDT elements' micro building blocks with the BWW ontology constructs.

It is recognised that we may need additional new constructs for aspects that are particular to DSR such as kernel theory/justificatory knowledge, or un/conceivable problem/need. The main difference with these aspects is that they may be abstracted/virtualized as not being available in the real world; see Figure 1 in Gregor and Jones [5]. Three possible conclusions are expected (BWW ontology constructs fit totally into all ISDT elements, fit with deficits, or do not fit totally) as we envisage ISDT and the BWW ontology constructs in a master-details (parent-child) relationship.

4.3 Results from the Mapping Exercise between IS Deep Structure Ontology and Information System Design Theory Elements

Table 1 shows the results from the mapping exercise. The first two columns in Table 1 illustrate the micro building blocks for each element of ISDT. The third column shows the result of the mapping exercise between key aspects in each element of ISDT and BWW ontology constructs.

Table 1. The Result of BWW Ontology and ISDT Elements Mapping.

Element	Key aspects in ISDT elements	IS ontology constructs
Purpose and scope	Design meta requirements. Design goals. Design Scope/Boundaries. Context/Environment in which the artefact is intended to operate.	System – system environment – input (component/state) - external event/transformation – output (component/state)
Constructs	Most basic level of ISDT. Represent physical phenomena. Represent abstract terms. Decomposition. Entities of interest.	Thing – attributes – property - state (stable/unstable) – system composition.

Principles of form and function	Principles define structure, organization, functioning. Functions. Properties. Features/attributes. “Blue print”/architecture. Relations.	Conceivable state space – lawful state space – Class – kind – coupling – system - subsystem – aggregate – system structure – system decomposition – level structure - internal event - transformation – lawful transformation – transfer function.
Artefact mutability	The degree of mutability of designed artefact. Changes in system state and changes that affect the basic form or shape of the artefact.	Equilibrium – History.
Testable proposition	Proposition: “if a system or method that follows certain principles is instantiated then it will work or etc” – heuristic propositions. Generality in terms of context and time.	Event – event space – lawful event space – transformation – lawful transformation – transfer function – well-defined event – poorly defined event.
Justificatory knowledge	Theories that link the mechanism for a number or all aspects of the designed theory/artefact. It may come from NS/SS/design theory/practitioner-in-use theory/evidence-based justification such as AR.	Law (natural and human) – state law
Principles of implementation	Process of how to build an artefact and bring it to reality How to implement it in practice.	NA
Expository instantiation	“A realistic implementation contributes to the identification of potential problems in a theorized design and in demonstrating that the design is worth considering”. Instantiated afrtifacts are things in the physical world, while theory is an abstract expression of ideas about the phenomena in the real world.	NA

4.4 Results Discussion

This exercise proves that there is reasonably good mapping between the ISDT’s elements as the high level specification, and BWW constructs as the detailed specification. Six elements have mapped to many constructs, which means the ISDT elements are more general than the BWW constructs. This confirms our initial expectations mentioned above. For instance, the element of principles of form and function is mapped to many IS constructs. Apparently, Table 1 confirms the high level specification of design knowledge of the design theory. Gregor and Jones [5] define a design theory as “something in an abstract world of man-made things, which also includes other abstract ideas such as algorithms”.

Since ISDT proposed by Gregor and Jones [5] is abstract/ general representation, we believe there are two issues here. Firstly, ISDT direct applicability to the practice is not easy for practitioners to use it in building their intended system. Practitioners need to transform ISDT into many forms until it becomes ready to implement and read by machine as depicted in Figure 3 between ISDT and its instantiation. Secondly, developing/theorizing design theory is not straightforward in the absence of detailed design constructs. Therefore, the results of the mapping exercise proposes BWW constructs that can be used as a base of constructs collection that both researchers in DSR or practitioners use in theorizing and instantiation processes, respectively – see Figure 4. Researchers in DSR use the constructs collection, fully or partially, to define their design which are then used in extracting general design knowledge to build the design theory. Subsequently, practitioners use the design theory in conjunction with the defined design constructs by the design theory creator.

Unexpectedly, this exercise reveals that ISDT is not totally parsimony, because some BWW ontological constructs are under more than one of the ISDT's elements. This indicates some overlaps between the ISDT's elements. An issue can be raised Is ISDT parsimony (unambiguously specified)?

Interestingly, the last two optional elements of the ISDT, Principles of Implementation and Expository Instantiation, have not been mapped to any of the BWW constructs. Based on the ontological view of artifact and design theory discussed in [38] and [5], we may explain why we have this case. For the latter element, it is not surprising, because it represents the IS itself which is the result of constructs representation. For the former element, it is complex to justify. Deep thinking of this situation and based on what this element means and the authors' understanding of design as process and product, this element of ISDT could be pulled and stretched across the first six elements of ISDT. The rationale behind this is that all BWW constructs used in the mapping actually represent and specify this element. The BWW constructs and the relationships between them symbolize the design as process. Therefore, the ISDT can be divided into three separate layers, each of which: 1) contains the first six elements of ISDT, 2) contains the Principles of Implementation element of ISDT, and 3) contains the Expository Instantiation element of ISDT. Figure 4 demonstrates these three layers. Moving towards the third layer from the first corresponds to the instantiation/de-abstraction process; however, moving the opposite way stands for the theorizing/abstraction process. Design researchers can start from any layer and develop the other layers subsequently or interchangeably. Recently, Kuechler and Vaishnavi [50] propose 'A Framework for Theory Development in Design Science Research: multiple perspectives'. Using this framework, we can find that the first and the third layers are located in this framework. The second layer which emerges from using the BWW ontology constructs may fit between the design theory and artefact components in their framework. Figure 4 may be injected into their framework.

Furthermore, we recognize that using the BWW ontology in DSR methodology (the DSR-Roadmap) provides interested design researchers or practitioners with traceability quality. Through this quality, they can trace the knowledge from their design to their design theory and vice versa. The traceability leads to apparent transparency which increases the credibility of the design.

Style is one of design's key aspects that affects the resultant product [39]. We believe the design style is a mirror of what represented inside the designed artifact/solution. Thus, in DSR using different BWW ontological constructs (any combinations), this influences delineating the design style making, it apparent to identify. Furthermore, Hevner et al. [27] suggest design style should be included in design evaluation. The BWW ontological constructs may simplify the evaluation of various designs. Since the combination of these constructs in the inner environment of the design represents the design style, this allows designers to predict the behaviour and effects of the design in response to the outer environment. Therefore, the BWW ontological constructs can be used to judge the quality of the design.

Finally, the mapping exercise shows that there may be a need for some new ontological constructs for aspects that are particular to DSR in IS. This issue needs further careful investigation.

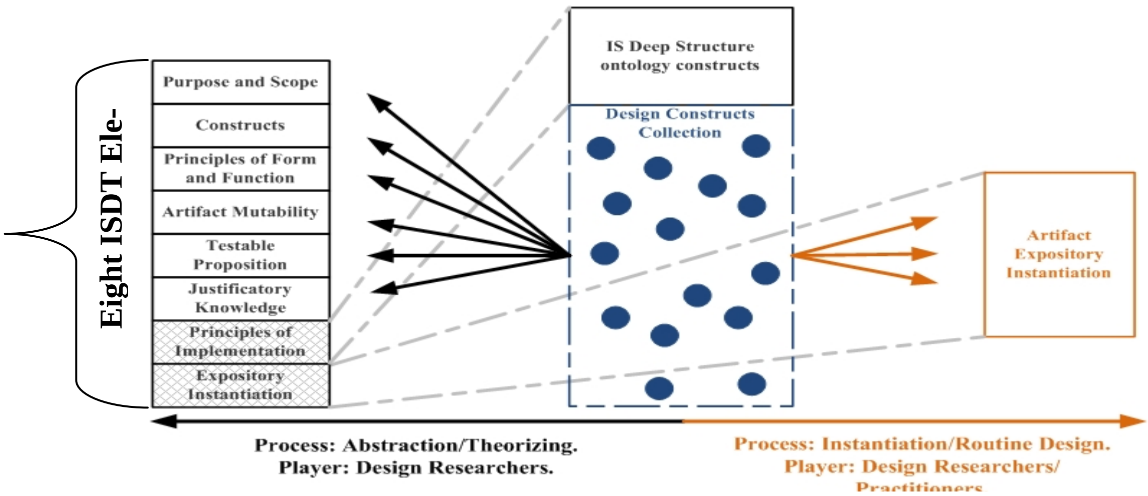

Fig. 2. The Three Layers of Information System Design Theory (ISDT)

5 Conclusion

This essay has argued that design needs to be specified more and should be included in DSR methodology; it is motivated by observed methodological shortcomings. The purpose of the paper was to search for design constructs to help design researchers to specify their design. It has justified and investigated the applicability of using the BWW ontology in DSR to include it in the DSR-Roadmap.

This paper has shown that the BWW ontology can be integrated into the DSR methodology. The following contributions can be drawn from the paper:

- Using the BWW ontology simplifies and contributes to the ISDT construction and implementation in abstraction and instantiation processes. This may help to establish common language that allows design researchers to effectively communicate their design with researchers and practitioners.

- The BWW ontology will explicitly strengthen the design of artefacts and make them easier, because it provides most if not all constructs that researchers need in order to complete their design.
- There is good mapping between the ISDT's elements and the BWW ontological constructs. Although there is overlap in this mapping, this confirms the high level design in ISDT.
- The ISDT could be divided into three layers: 1) its first six elements, 2) the seventh element, and 3) the last element of ISDT. This allows researchers to trace the design and recognise its style.
- The mapping exercise shows potential needs for some new ontological constructs to satisfy the special nature of knowledge in DSR.

The obvious limitation lies in the fact that the mapping exercise is one author coded. For future work, further researchers need to conduct this mapping exercise, with other coders following the same procedure so as to support the results and resolve any conflicts. Another possible work to test the proposal in this paper would be to take an published ISDT and investigate the possibility of building its specification using the constructs of the BWW ontology. Furthermore, there might be the need to consider all three models (representation model, state track model, and decomposition model) proposed by Wand and Weber.

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Appendix A: IS Deep Structure Ontology Constructs (as described in [3])

Construct	Explanation
Thing	A thing is the elementary unit in the BWW ontological model. The real world is made up of things. Two or more things (composite or simple) can be associated into a composite thing.
Properties	Things possess properties; A property is modelled via a function that maps the thing into some value. A property of a composite thing that belongs to a component thing is called a hereditary property. Otherwise it is called an emergent property. Some properties are inherent properties of individual things called intrinsic. A property that is meaningful only in the context of two or more things is called a mutual or relational property. Attributes are the names that we use to represent properties of things.
State	The vector of values for all property functions of a thing.
Conceivable state space	The set of all states that the thing might ever assume.
State law	Restricts the values of the property function of a thing to a subset that is deemed lawful because of natural laws or human laws.
Lawful state space	The set of states of a thing that comply with the state law of the thing. It is usually a proper subset of a conceivable state space.
Event	A change of state of a thing. It is effected via a transformation.
Event space	The set of all possible events that can occur in the thing.
Transformation	A mapping from a domain comprising states to a co-domain comprising states.
Lawful transformation	Define which events in a thing are lawful.
Lawful event space	The set of all events in a thing that are lawful.
History	The chronological ordered states that a thing traverses.
Coupling	A thing acts on another thing if its existence affects the history of the other thing. The two things are said to be coupled or interact.
System	A set of things is a system if, for any bi-partitioning of the set, coupling exists among things in two subsets.
System composition	The things in the system.
System environment	Things that are not in the system but interact with things in the system.
System structure	The set of coupling that exist among things in the system and things in the environment of the system.
Subsystem	A system whose composition and structure are subsets of the composition and structure of another system.
System decomposition	A set of subsystems such that every component in the system is either one of the subsystem in the decomposition or is included in the com-

	position of one of the subsystems in the decomposition.
Level structure	Defines a partial order over the subsystem in a decomposition to show which subsystems are component of other subsystems or the system itself.
Stable state	A state in which a thing, subsystem or system will remain unless forced to change by virtue of the action of a thing in the environment (an external event)
Unstable state	A state that will be changed into another state by virtue of the action of transformation in the system.
External event	An event that arises in a thing, subsystem or system by virtue of the action of some thing in the environment on the thing, subsystem or system. The before-state of an external event is always stable. The after-state may be stable or unstable.
Internal event	An event that arises in a thing, subsystem or system by virtue of law-ful transformation in the thing, subsystem or system. The before-state of an internal event is always unstable. The after-state may be stable or unstable.
Well-defined event	An event in which the subsystem state can always be predicted given the prior state is known.
Poorly defined event	An event in which the subsequent state cannot be predicted given the prior state is known.
Class	A set of things that possess a common property.
Kind	A set of things that possess two or more common properties.